

Plant-Based Insect Repellents: Is That a Sustainable Option to Curb the Malaria Burden in Africa?

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Arthropod-borne diseases are the major causes of morbidity and mortality in the resource-constrained tropical and subtropical countries. Particularly the devastating nature of malaria in sub-Saharan Africa (SSA) is indubitably intolerable [1]. The recent WHO Malaria Report 2011 [2] estimated that 3.3 billion people were at the risk of malaria in 2010, and of all geographical regions, populations living in sub-Saharan Africa (SSA) have the highest risk of acquiring malaria; among 216 million episodes of malaria in 2010, of which approximately 81%, or 174 million cases, were observed from the African Region. There were an estimated 655,000 of malaria deaths in 2010, of which 91% were from Africa.

The reasons for the heavy malaria burden in the SSA are mainly due to the ideal climatic conditions for the breeding of the world's most effective malaria vector *Anopheles gambiae* sensu lato (s.l.) complex, the shortage of committed resources and trained personnel, the lack of commitment from governments and communities ravaged by the disease and the poor infrastructural capacities for malaria control [3]. Furthermore, we cannot ignore the fact that the widespread poverty in the SSA countries plays a greater role in the continuing burden of malaria [4]. In general, with a potential dual causation between poverty and malaria, the poor households experience high malaria prevalence that in turn prevails them in poverty and traps them in reinforcing cycles [5].

At present, malaria control is one of the most challenging and serious tasks, owing to the spread of multidrug-resistant strains of *Plasmodium falciparum*, fragile health infrastructure, insecticide resistance, and eco-system degradation. Vector control is a powerful weapon in the fight against vector-borne diseases and is considered to be a cornerstone in malaria control and in managing vector populations to reduce/interrupt the transmission of disease [6].

To minimize the dependency on chemical insecticides, efforts have been made to search and develop alternative vector control interventions [6]. Although, non-insecticide based approaches like biological control and environmental management are efficient and effective under the appropriate settings, it may not provide total malaria control during the epidemic season.

Indoor-based residual insecticide and bed net-based approaches have been proven effective against epidemiologically important, endophilic anopheline vectors [7]. However, some insecticides have excito-repellency properties, which may induce the selection for outdoor biting behaviours, where indoor-based insecticidal measures selectively kill indoor feeding/resting mosquitoes [8,9].

Currently we are highly dependent on the pyrethroids, the only class of insecticides used on long lasting insecticide-treated nets (LLINs). Resistance to pyrethroids has now been identified in a wide variety of settings, most highly in malaria-endemic countries of Africa [2] and this could be a major setback in the ongoing sustainable malaria interventions in the SSA.

Besides, indoor-based interventions do not suffice to reduce malaria transmission to desired levels, as blood feeding and resting occurs outdoors in significant proportions [7]. The data presented in the recent works by Russell et al. [10] and Reddy et al. [11] suggests that the long-term indoor application of residual insecticides (IRS) induce the tendency for outdoor feeding. This is expected to erode the efficacy of indoor-based interventions over time, much as increased insecticide resistance would [12]. The outdoor biting behavior of anopheline vectors indicates that it is imperative to explore possibilities for outdoor anti-vector interventions, in combination with the ongoing IRS and LLINs distribution [11]. The increased international travel and movement of people from urban to rural areas expose many civilians to the arthropod-borne diseases [13,14]. Consequently, the above stated issues have posed a serious threat to the current malaria control triumph. In this context, repellents could play the pivotal role as repellents are extremely useful and helpful whenever and wherever other personal protection measures like ITNs are impossible or impracticable [15].

Insect repellents may be chemical or plant-based substances, preventing from arthropod bites, which eventually help to achieve the reduction of man-vector contact. Repellents are typically applied to exposed skin or can be applied to clothing or other surfaces to discourage arthropods from landing or climbing onto treated surfaces [16].

DEET (N,N-diethyl-3-methylbenzamide) has been the most extensively used personal arthropod repellent for over five decades and it can be applied to exposed skin or clothing [17]. Although DEET is used by 30% of the US population, it has been identified that it can cause environmental and human health risks [18]. Generally, synthetic repellents have several limitations, including reduced efficacy owing to sweating, unpleasant odor, expensive and can cause allergic reactions [6]. Besides their toxicity and adverse side effects, a few of them require electricity for their usage too [19]. An ideal repellent should provide protection against a broad spectrum of blood-feeding arthropods for at least 8 h, be non-toxic, non-irritating, odorless, and non-greasy [20] and such a repellent is yet to be developed [21].

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The repellent properties of plants to mosquitoes and other pest insects were well known before the advent of synthetic chemicals [22]. This repellency of plant material has been exploited for thousands of years by man, most simply by hanging bruised plants in houses, a practice that is still in wide use throughout the developing countries [23]. In Africa, many villages don't have proper well-fixed electricity systems, where traditional plant-based insect repellents could extremely be useful in the remote rural areas. Furthermore, plant-based repellent products are inexpensive, easily available, locally known, and culturally acceptable [19]. Even today in majority of the African town variety of plant-based insect repellents are abundantly Available in markets.

Most of the problems of mosquito-borne diseases occur in low-income tropical communities but these communities have the advantage of accessing to thousands of species of plants containing useful phytochemicals to control both agriculturally and medically important insects [24]. Local plants with repellent or insecticidal action may play an important role in regions where mosquitoes bite in the early evenings or in situations when there are not enough bed nets to cover all the beds in a house [25]. Plants have been used since ancient times to repel/kill blood-sucking insects in the human history and even today, in many parts of the world people are using plant substances for the same [26]. Globally, numerous studies evidently suggest that the traditionally used plant-based insect repellents are promising and could potentially contain vectors of the disease. This appropriate strategy affords for the opportunity to minimize chemical repellents usage and the risks associated with the adverse side effects [27]. In fact many other key challenges and issues lie ahead for the advancement of the ideal insect repellent.

Undeniably, malaria is one of the most significant threats to human health imposing a severe socioeconomic burden in sub-Saharan Africa. Moreover, in the present scenario no single malaria control measure is sufficient to reduce malaria in any given setting. However, if an entire package of locally appropriate interventions could reach a sufficient level of coverage, then it might be possible to reduce the burden of malaria and achieve the malaria-related Millennium Development Goals [28]. It's quite interesting to note that the African *An. gambiae* (s.l.) complex contains the world's most efficient vectors of human malaria that feeds from outdoor victims being not protected by IRS or LLINs [11]. Therefore, merely insect repellents alone cannot minimize the malaria burden in Africa; however it could serve as a supplementary/alternative control measure in combination with ongoing anti-vector interventions.

At the moment, there is a general consensus that plant-based products are safe and the bio-active phytochemicals are easily biodegradable which creates a renowned interest both among the researchers and people. Usage of plant-based insect repellents is an integral and fundamental part of African social life and culture. The smoke of the dried repellent plant materials by smoldering through traditional charcoal stove drives-away insects/mosquitoes effectively in the early evening/morning times. It earns more interest as majority of the commercialized mosquito repellent products are derived from the well-known pyrethrum (Golden flower) plant [Asteraceae; *Chrysanthemum cinerariaefolium* (Current species name: *Tanacetum cinerariifolium*)] from East Africa. Numerous widely-known repellent plants are in use by the indigenous rural people in the SSA countries though they are quite unaware of the complete elucidation of the mechanism of repellency of those plants.

Furthermore analysis and scientific experiments are required to identify whether the bio-active molecules of the repellent plants have greater effect on the vectors rather than the intrinsic nature of smoke and also to evaluate the rate of effectiveness of the repellent plants and their insecticidal activities. Besides these, testing for their mammalian toxicity is also required to be warranted. Indeed, the main objective of conducting research on these plants is to build the bridge between laboratories and these communities eventually benefiting the commonmen. But the majority of the research conducted in the Africa on plant-based insect repellents has just ended with a research finding and only a very few of them have been commercialized. It's mainly due to the lack sophisticated laboratory services, inadequate funds and deficiency of regional and international support. The collaboration among the academia, government and the private sector is extremely important and imperative at this juncture. Therefore, providing well-funded and technically feasible conducive environment for the researchers is extremely important to improve the understanding of the repellent mechanisms and the traditional evaluation of repellent compounds. In addition, conducting intensive research and development toward the identification of novel low-cost, more effective and affordable plant based insect repellents is quite essential and inevitable for the sustainable reduction of malaria burden in Africa in the near future.

Definitions

Malaria is an infectious disease characterized by cycles of chills, fever, and sweating, caused by a protozoan of the genus *Plasmodium* in red blood cells, which is transmitted to humans by the bite of an infected female anopheles mosquito.

Vector control is any method to limit or eradicate the insects or other arthropods which transmit disease pathogens. It remains as the most generally effective measure to prevent malaria transmission.

Insect repellent is a substance applied to skin, clothing or other surfaces that repel the insects/mosquitoes from landing or climbing on that surface. Insect repellents help to prevent and control the outbreak of insect-borne diseases such as malaria, Lyme disease, dengue fever, bubonic plague, and West Nile fever.

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